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TO STUDENTS OF ARCTIC EXPLORATION

THE GEOGRAPHIC POSITION OF CAMP JESUP, AND THE REDUCTION OF THE OBSERVATIONS OF R. E. PEARY, IN THE VICINITY OF THE NORTH POLE

GIFT
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by

THOMAS H. HUBBARD, HUGH C. MITCHELL, C. E., AND
CHARLES R. DUVALL, B. S.

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TO STUDENTS OF ARCTIC EXPLORATION

THOMAS H. HUBBARD, New York

The Peary Arctic Club and the distinguished explorer whose name it bears have constantly desired scientific criticism of the observations and records made during the expedition of 1908-1909 to the North Pole.

To protect them from simulation, or other improper use, their publication has been deferred; but they have been repeatedly submitted and offered to impartial and reliable bodies qualified to determine their value.

On his return from the north and before he had reached the United States, Peary publicly declared in September 1909 that he wished to receive no honors or ovations until his right to them was settled and that his own records and proofs would be submitted forthwith to any competent body that might be selected to examine and pass upon them.

The reason for this was not that explorers, or scientists, or those who know the man, would question the correctness of Peary's own report.

Many times through a period of twenty three years he had returned from the Arctic. Sometimes he had brought back the report of unexampled success: as when twice he had crossed the interior of Greenland; as when he had defined Greenland's insularity and had rounded its extreme northern point; as when he had extended the explored limits of northern and western Grantland. Sometimes he had brought back the report of unsuccessful effort: as when in April 1902 on his sixth journey to the Arctic, he turned back at 84° 17′ north latitude and wrote in his diary "The game is off. My dream of sisteen years is ended... I have made the best fight I know. I believe it has been a good one. But I cannot accomplish the impossible"; as when in April 1906, again on the

Sea Ice, he turned back at 87° 06′ north latitude and wrote: "I should have liked to leave everything at this camp and push on for the one march with one empty sledge and one or two companions; but I did not dare to do this owing to the condition of the ice... In this last spurt we crossed fourteen cracks and narrow leads which, almost without exception, were in motion... I felt that the mere beating of the record was an empty bauble, compared with the splendid jewel on which I had set my heart for years and for which, on this expedition I had almost literally been straining my life out. I was more than anxious to keep on; but as I looked at the drawn faces of my comrades, at the skeleton figures of my few remaining dogs; at my nearly empty sledges and remembered the drifting ice over which we had come and the unknown quantity of the 'big lead' between us and the nearest land, I felt that I had cut the margin as narrow as could reasonably be expected. I told my men that we should turn back from here."

Always Peary has reported, as a real explorer should report, exactly what he has accomplished. Always he has given the true record, whether it was what he had hoped it might be, or fell short of his hope.

This is why, for many years, explorers and scientists have accepted his reports as true beyond cavil.

This faith in Peary was fittingly expressed by Major Darwin, the President of the Royal Geographical Society, when in conferring the Society's Special Gold Medal he greeted Peary as the only man who, since the world began, had ever led a party of his fellow creatures to one of the poles of the earth; who stated that the fact that the Society's Gold Medal had been awarded to Peary in 1898 was sufficient proof that he was an Arctic traveler of the highest reputation and who, referring to the many arduous journeys, full of dangers and difficulties and the large amount of scientific work done and the increase of Geographical knowledge accomplished by Arctic explorers, reminded his distinguished audience that Peary's expeditions formed no exception to this honorable record and that this should not be forgotten, because it had been the policy of the Society not to honor any mere race to the Pole.

It was the same faith that caused former President Roosevelt, to send from remote Africa his cordial congratulations for Peary's report of final success and, later, to write: "Commander Peary has made all dwellers in the civilized world his debtors, but above all,

we his fellow Americans are his debtors. He has performed one of the greatest feats of our times; he has won high honor for himself and for his country. „

Many may think that this faith and these expressions of confidence in Peary and the cordial recognition of his great achievement attested by medals of learned societies of Europe and of his own country make further examination or discussion superfluous.

Yet there remain these reasons for scientific criticism.

The uninformed must be brought to know, as the well informed already know, that the attainment of the Pole, or of any point of latitude, is susceptible of mathematical proof and does not depend on mere assertion.

An epochal, world-important achievement should be coupled with records permanent and historic, and not merely with congratulations and speeches that are ephemeral.

Following Peary's announcement made upon his return that his records and proofs would be submitted to any competent body that might be selected to examine and pass upon them, some discussion ensued, in which he took no part, as to what selection should be made. In this discussion officials of the American Musem of Natural History of New York, the American Geographical Society of New York, the National Academy of Science, the National Geographic Society of Washington and others took part.

It resulted that at a meeting of the Board of Managers of the National Geographic Society of Washington, on October 20th, 1909, the records and observations and proofs of Commander Robert E. Peary that he reached the North Pole April 6th, 1909, were submitted to the Society. The records and observations were immediately referred to the Committee of Research with the direction that the Chairman appoint a Sub-Committee of experts of which he was to be a member, to examine the records and report on them to the board.

The Committee of experts, composed of Henry Gannett, President of the Society, Rear-Admiral Colby M. Chester and O. H. Tittman, Superintendent of the U. S. Coast and Geodetic Survey, men of the highest qualifications for the work, reported November 4th to the Society that the Committee had examined Commander Peary's original journal and records of observations, together with all his instruments and apparatus and that its members were unanimously of the opinion that he reached the North Pole on April 6th, 1909, and that the organization, planning and management

of the expedition, its complete success and its scientific results reflect the greatest credit of his ability.

The report was approved by the Society's board.

A subsequent examination by the Royal Geographical Society of London approved the result reached by the National Geographic Society.

In his annual message to Congress in December 1910 President Taft said: " The unparalleled achievement of Peary in reaching the North Pole April 6th, 1909, approved by the critical examination of the most expert scientists, has added to the distinction of our Navy to which he belongs and reflects credit upon his country. His unique success has received generous acknowledgement from scientific bodies and institutions of learning in Europe and America. I recommend fitting recognition by Congress of the great achievement of Robert Edwin Peary. "

Acting upon the recommendation of President Taft the Committee on Naval Affairs of the United States House of Representatives reported a bill that authorized the President of the United States to place Peary on the retired list of the Corps of Civil Engineers of the United States Navy with the rank of Rear-Admiral to date from April 6th, 1909, with the highest retired pay of that grade under existing law. The bill also tendered to Peary the thanks of Congress for his Arctic explorations resulting in reaching the North Pole.

This bill passed both houses of Congress, was signed by President Taft March 4th, 1911, and a commission in accordance with its terms was issued to Rear-Admiral Robert E. Peary. The Committee on Naval Affairs of the United States House of Representatives, charged with the consideration of President Taft's recommendations, reported that Robert E. Peary reached the North Pole on April 6th, 1909. From a camp (Camp Jesup) which he established at a point estimated by observation at 89° 56′ north latitude on said date (slightly over four miles from the exact pole) he made two excursions on that and the following day which carried him close to and beyond the pole. The Committee reached its conclusion after a careful examination and hearing by its sub-committee extending over several days at which Peary appeared in person and gave important testimony, submitting all his papers, original data, daily journal and notes of astronomical observations and soundings, etc. The Committee also heard the report of the National Geographic Society of Washington; the report from the President

and one of the Board of Governors of the Royal Geographical Society of London, which Society, through its official compute, had made independent examination of the data and proofs, and also a report from Hugh C. Mitchell and C. R. Duvall, expert computers of astronomical observations from the Coast and Geodetic Survey of the United States. These men independently of any other person, working on the original data of the observations taken by Peary, stated before the committee that on the above named dates Peary passed within a little over a mile of the exact pole and stated, in conclusion that the march of April 7th, 1909, may have carried Peary even within a stone's throw of that point.

The report of the House Committee on Naval Affairs gives by reference, or directly, the information on which the committee acted and is in itself an historic document of first importance.

The conclusions of Hugh C. Mitchell and Charles R. Duvall showing that Peary went within a mile and six tenths of the pole and possibly within a stone's throw of that mathematical point and that he went beyond the pole, are also of permanent historic importance. It is doubtful whether the difficulties of exact observations would permit a closer touch of the precise point, even if a hundred expeditions could safely reach as high latitude by travel over unobstructed routes. The Mitchell and Duvall conclusions are so convincing in themselves and are such high tributes to Peary's accurate work that their methods of computation and their mathematical processes are now given in extenso to the scientific world and to the public.

THE GEOGRAPHIC POSITION OF CAMP JESUP, AND THE REDUCTION OF THE OBSERVATIONS OF R. E. PEARY; IN THE VICINITY OF THE NORTH POLE, BY HUGH C. MITCHELL C. E. AND CHARLES R. DUVALL B. S.

In this paper it is desired to present in as complete form as possible the results and discussion of the astronomic observations made by Commander (now Rear-Admiral) R. E. Peary U. S. N. and members of his party during the expedition of March and April 1909, which resulted in the discovery of the North Pole. In connection with this there are also presented certain data relating to observations made with a sextant and mercurial horizon, after the manner followed by Peary, which are intended to illustrate the possibilities of these instruments, and which throw direct light on

the question as to whether the observations submitted by Peary were physically possible, and what degree of accuracy might be claimed for them.

This paper in no way modifies the substance of the report made in February 1911, to a sub-committee of the Committee on Naval Affairs, U. S. House of Representatives, but is merely an amplification of that report, with certain additions thereto.

These computations of the observations taken by Peary and by members of his party are, for the sake of convenience, here arranged and discussed in chronological order.

For the observations of March 22, 25, and April 1, the computations are necessarily based upon the assumption that Peary was following closely the meridian of Cape Columbia. This assumption is necessary, since on each of the dates mentioned, but a single set of observations of the sun's altitude was obtained, and it not being possible to observe culmination, one element of dead reckoning, namely direction, must be introduced in order to obtain a position. How justifiable this assumption is will appear later, when the observations at Camp Jesup are reduced, for at that point two complete sets of observations taken six hours apart give a good determination of position independent of any such assumption as is stated above. It is there shown that Peary, at the end of his journey north, was within five miles of the meridian of Cape Columbia, and therefore it seems reasonable to assume that he was never at any point of the journey more than ten miles from that meridian.

It may be well at this point to state the well known fact that a single observation of the altitude of a celestial body *does not* fix the position of the observer on the earth, but determines a so-called circle of position, which is the locus of all points on the earth at which the given altitude might have been observed at the same instant. This so called circle is one which has for its center, in the case of the sun, the sub-solar point or point on the earth directly under the sun at the time of the observation, and for its radius the true zenith distance of the sun expressed as an arc of a great circle of the earth. This is only approximate as the earth is not a sphere, but the approximation is sufficiently close for navigation.

From the above it is quite obvious that if at any one point two observations be made on the sun (or other heavenly body) at different times of day, that is, separated by a time interval, two

circles of position will be determined and the point of observation will have to be at one of the two points of intersection of the two circles (since it must be on both circles).

In the case of Camp Jesup it is easy to determine by inspection which intersection fixes the position of the observer, since of the two intersections, one is near the North Pole, and the other is in or near the Antarctic regions.

We have then the position of Camp Jesup determined by that method, the graphical solution of which is known to all navigators as the Sumner Method, a method of position determination well adapted to practical navigation. These two sets of sun altitude measures, with an intervening interval of 6 hours, give the strongest possible determination of position, as is immediately seen from the practically perpendicular intersection of the Sumner lines, and as is also evident in the corresponding stability of the trigonometric solution. It would have been highly desirable to have had a complete third set of observations from the same point, and at an interval of 12 hours from either of the two sets actually taken. The resulting position would have then been practically independent of error in refraction correction, and furthermore would not have been sensitive to uncertainties in the clock correction. Additional sets of observations at about the 6-hour interval would have added much value, of course, by furnishing material from which the probable error of the position could have been determined. Definite information in regard to the motion of the ice would have also been furnished by additional observations. It must be remembered, however, that the observations were made under the most trying circumstances, when every minute of time counted, and the eyes of the observer had to be considered.

THE INSTRUMENTS.

All observations of the double-altitude of the sun by Peary or members of his party on the sledge expedition of March and April 1909, were made with a sextant and an artificial horizon (mercurial). The sextant was a navigators sextant of standard make, with a limb read by vernier to 10″. The mercurial horizon was unique in several particulars. The trough to contain the mercury was made of wood, which provided better insulation than the metal pans ordinarily used. This wooden trough had the outer ends bevelled, to fit the sloping faces of the wind shield. The wind shield was so modified that the trough of mercury fitted

snugly into it, and in such a manner that there was no obstacle in observing the sun at low altitudes. For observing, the wooden trough was filled to the brim with mercury, which was returned to the carrying case (a tube) in the following novel manner. In one corner of the trough was a hole in which was a long wooden plug inserted from the upper side. When observations were completed and it was desired to return the mercury to the tube, the trough was held with the hole directly over the carrying case. This was easily accomplished by placing the lower end of the plug within the mouth of the tube, the plug being then removed and the mercury allowed to run through the hole into the tube.

THE COMPUTATIONS.

It has been the endeavor to put the following computations in such form as to require little explanation. Any comment pertinent to a particular computation will be made immediately following that computation or group of computations.

THE CORRECTION FOR REFRACTION.

The value of the correction to the observed altitude due to refraction was computed from the formula given by Chauvenet, vol. 1, (5th edition), page 131, viz.:

$$r = \alpha\ \beta^{A}\ \gamma^{\lambda} \tan z$$

Bessel's refraction tables were used. No account was taken of the term β^{A}, which represents the reduction for barometer reading, no values for height of barometer being available. It is believed, however, that in no case could this correction (β^{A}) affect the final result of the latitude by as much as 1′.

THE WATCH CORRECTION.

The standard chronometer carried on the S. S. Roosevelt, Bliss 2998, was compared with Greenwich mean time before the expedition left New York and after its return to that port. The results of the comparisons were as follows:

July 3, 1908, fast, G. M. T. . . .	0 min.	25.8	sec.
Predicted daily rate, losing		0.2	"
October 7, 1909, fast, G. M. T. .	17 "	12.9	"
Average daily rate, 461 days, gaining		2.2	"

According to the predicted daily rate the chronometer was approximately $^1/_2$ minute slow on G. M. T. at the time of the sledge expedition to the pole in March and April 1909, while in reality, as shown by the average daily rate for 461 days, it was then 9 minutes fast on that time. The time used on the sledge journey was the same as was used in all the tidal work of the expedition, namely, Intercolonial or 60th meridian mean time.

The watches carried by members of the sledge expedition being set $^1/_2$ minute fast on a chronometer which was supposed to be $^1/_2$ minute slow, but which was in reality more than 9 minutes fast, must have been about 10 minutes fast on the standard time. Only two of those watches went to the pole and back in good condition, one of them being the watch* which has been carried by Peary for a number of years. It showed a total gain of less than 1 minute from the time of leaving the ship until the return thereto.

The best value we have then, for the correction to the watch times of the observations discussed herein, is —10 minutes, that is, the watch was 10 minutes fast on 60th meridian mean time.

That this correction is very close to actual fact may be seen by reference to Dr. R. A. Harris' paper on Arctic tides, published in 1911 by the Coast and Geodetic Survey. On page 8 of that publication Dr. Harris states that a check on the reliability of the time correction (used in the tidal discussion) is afforded by the value of M_2° at Fort Conger as derived from the observations by a member of Peary's party in 1909, taken in comparison with the value obtained from a long series of observations by the Greely expedition. This and the other checks mentioned therein show discrepancies of less than 5 minutes, and it is therefore safe to say that the correction to the time used in the tidal observations, and therefore to that kept by the standard chronometer on board the S. S. Roosevelt, as computed with the mean rate of 461 days was never at any time during the expedition in error by as much as 5 minutes

As stated later an error of 10 minutes in the time of observations at Camp Jesup would change the latitude of that place by only about 6″, or less than 200 meters.

MARVIN'S AND BARTLETT'S OBSERVATIONS.

The observations of March 22 and 25 and of April 1 were computed according to the well known formula for observations on the meridian:

$$\varphi = \delta \pm z$$

which in this case becomes:

$$\text{Latitude} = \text{declination} + \text{zenith distance.}$$

Following the computation of April 1 is given a table which shows the corrections to the latitudes for ex-meridian observations.

Computation of Marvin's observation of March 22th, 1909.

	10°	24′	50″	
	10	24	30	
	9	21	20	
	9	21	50	
	9	21	10	
	9	21	00	
	10	24	30	
	10	24	20	
	9	52	56	Mean
		1	55	Index correction
	9	54	51	
	4	57	26	Apparent h
—		12	12	Refraction corr'n
+			9	Parallax
	4	45	23	True h
	85	14	37	True zenith distance (z)
+	0	34	20	δ

85 48 57 = Latitude of point of observation, provided that the observer was on the 70th meridian west of Greenwich.

This latitude has had no ex-meridian or clock error correction applied to it. Together they amount to less than 1′.

COMPUTATION OF REFRACTION CORRECTION

Temperature : — 40° F.

$\gamma \ldots\ldots = 1.2103131$

$\log \gamma \ldots = 0.08290$

$\lambda \ldots\ldots = 1.1289$

$\log (\gamma^{\lambda}) . = 0.09817$

$\log \alpha \ldots = 1.70949$

$\log \tan z = 1.06180$

$\log r \ldots = 2.86446$

$r = 732'' = 12'\ 12''$

COMPUTATION OF PARALLAX CORR'N.

horizontal $p. = \pi = 8''.8$

$\log 8.8 \ldots\ldots = 0.944$

$\log \sin z \ldots = 9.998$

$\log$ parallax . = 0.942

parallax . . . = 9″

MEAN TIME OF OBSERVATION

1 p.m. (60th meridian) = 5 p. m. G. M. T.

$\delta' = +\ 0°\ 29'\ 24''$

$\Delta = +\ \ \ 4\ \ 56$

$\delta = +\ 0\ \ 34\ \ 20$

Computation of Marvin's observation of March 25th, 1909.

	11°	04′	10″	
	11	04	30	
	10	02	00	
	10	02	10	
	10	02	30	
	10	02	20	
	11	04	20	
	11	04	50	
	10	33	21	Mean
		2	44	Index corr'n
	10	36	05	
	5	18	02	Apparent h
—		10	40	Refraction corr'n
+			9	Parallax
	5	07	31	True h
	84	52	29	True zenith distance (z)
+	1	45	16	δ

86 37 45 = Latitude of point of observation, provided that the observer was on the 70th meridian west of Greenwich, and that the temperature was — 10° F.

A temperature of — 40° F. would make the latitude 51″ greater.

No correction for ex-meridian or clock error has been applied.

$\delta' = +\ 1°\ 40'\ 21''$ G. M. noon

$\Delta\quad +\quad 4\ \ 55$

$\delta\ = +\ 1\ \ 45\ \ 16$

$\pi = 8''.8$, log $= 0.944$

log sin z $\quad 9.998$

log parallax $= 0.942$

parallax $= 9''$

COMPUTATION

OF REFRACTION CORRECTION.

Temperature not recorded, but in his field computation Marvin uses — 10° *F.*; but on March 22 he also computes with — 10°, when his record was — 40°. This is because — 10° *F.* is the limit of his tables.

I. Using — 10° *F.* $\lambda = 1.1139$

log γ . . . . = 0.05307

log(γ^λ) . . = 0.05911

log α . . . . = 1.71473

log tan z . = 1.03261

log r . . . . = 2.80645

$r = 640'' \quad = 10'\ 40''$

II. Using — 40° *F.* (or *C.*)

λ . . . . . . = 1.1139

log γ . . . . = 0.08290

log (γ^λ) . . = 0.09234

log α . . . . = 1.71473

log tan z . = 1.03261

log r . . . . = 2.83968

$r = 691''$. = 11′ 31″

This value of r is 51″ greater than for a temperature of — 10° *F.*

Computation of Bartlett's observation of April 1st, 1909.

	13°	09′	00″	Observation on ☉
		4		Index corr'n
	13	13	00	
	6	36	30	Apparent h of ☉
—		8	48	Refraction
+		16	02	Semi-diameter
+			9	Parallax
	6	43	53	True h of sun's center
	83	16	07	True zenith distance (z)
+	4	28	42	δ

87 44 49 = Latitude of point of observation provided that the observer was on the 70th meridian, and observed at local noon.

COMPUTATION OF REFRACTION CORRECTION.

Temp. = — 10° $F.$ (record not clear)

λ . . . . = 1.0825

log γ . . . . = 0.05307

log (γ^{λ}) . . = 0.05745

log α . . . . = 1.72925

log tan z . = 0.93610

log r . . . . = 2.72280

r = 528″ = 8′ 48″

Had the temperature been + 10° F a similar computation would give r = 8′ 24″, only 24″ less than for temp. = — 10°.

COMPUTATION OF PARALLAX.

π = 8″. 8, log π . . . . = 0.944

log sin z . . = 9.997

log parallax = 0.941

parallax. . . = 9″

IF THE SUN WAS OBSERVED CROSSING THE 70TH MERIDIAN.

δ' = + 4° 24′ 12″

Δ = + 4 30

δ = + 4 28 42

CORRECTIONS TO LATITUDE FOR EX-MERIDIAN OBSERVATIONS.

The following table was computed from the formula given by Chauvenet (vol. 1, p. 233) for the reduction of ex-meridian observations for latitude, and the formula already given for the computation of latitude from observations on the meridian. These formulae are as follows:

$$\cos z \text{ (on meridian)} = \sin h + \cos \varphi\text{-}\cos \delta, (2 \sin^2 \tfrac{1}{2} t)$$

and

$$\varphi = \delta + z$$

The quantities in the table are the corrections to the latitude (φ) as computed from the second formula given above. These corrections are all negative, decreasing the latitude as computed in the preceding pages.

Table of corrections to φ.

Ex-meridian distance	Corrections to computed latitude		
	At latitude 85° 48′ 57″ (March 22)	At latitude 86° 37′ 45″ (March 25)	At latitude 87° 44′ 49″ (April 1)
1°	2″	2″	0″
2	9	7	5
3	21	17	11
4	37	30	20
5	58	46	31
6	1′ 23	1′ 07	44
7	1 53	1 31	1′ 00
8	2 27	1 58	1 19
9	3 06	2 30	1 40
10	3 49	3 05	2 03
Length of 1° of the parallel in geographic miles.	4.4	3.5	2.4

From this table it is seen that in order to produce an error of 1′ in any one of the three computed latitudes just shown, the observer would have to observe the sun off his meridian by amounts

of 5°, 6°, and 7°, respectively for the observations of March 22, 25, and April 1. In these latitudes, 5°, 6°, and 7° measured on the parallels would equal 22, 21, and 17 geographic miles respectively. This suffices to show, when considered in connection with the fact that the journey north was finished within 5 miles of the meridian of Cape Columbia, that none of the latitudes computed for March 22, 25, and April 1, can be in error by as much as 1′ due to the observer and the sun not being on the same meridian at the time of the observation.

GEOGRAPHIC POSITION OF CAMP JESUP.

The first observation obtained at Camp Jesup, was made at noon of April 6. This observation is imperfect (incomplete) and uncertain, having been made through clouds which prevented complete observations. It serves however as a rough check on the complete observations which were obtained 24 hours later.

The position of Camp Jesup is well fixed by two complete sets of observations on the sun, made on the date April 7th, at 6h 30m a. m. and at 12h 30m p. m., 60th meridian mean time.

In reducing these observations to a position the two co-authors of this paper followed different routes, obtaining thereby safe and satisfactory checks on the mechanical operations of the computations as well as on the theory of the problem.

Mr. Mitchell followed the method and formulae produced on page 260, volume 1, of Chauvenet's astronomy. His solution is given first.

Mr. Duvall, whose computation is placed immediately after that of Mr. Mitchell, used the *s* formula of spherical trigonometry, and by means of a series of approximations deduced a value for the latitude which satisfied the conditions imposed by the problem.

The problem is this: Two spherical triangles are considered; these triangles have for common vertices the pole and the zenith of Camp Jesup. The third vertex of each triangle is the position of the sun at the time of observation, namely, one is the position of the sun at 6h 30m a. m., April 7, 1909, and the other its position at 12h 30m p. m. of thes ame day. In these triangles we have the two sides corresponding to the two zenith distances (observed); the two sides corresponding to the two values of the co-declination of the sun at the two times of observation; and the difference of the two angles at the pole, which is equal to 90° and is the difference of the two hour angles of the sun. We have the further

condition that the third side of the two triangles is common to both, and is equal to the co-latitude. By a series of approximations Mr. Duvall determined a value for this third side, the co-latitude, which would complete the two triangles and give values for the two angles at the pole differing by exactly 90°. The problem proved a determinate one, the difference in the two angles at the pole being very sensitive to small changes in the assumed co-latitude. Only the final approximation of this computation is shown here.

Peary's observations of April 6th, 1909, 12h 50m p. m. (watch)

at Camp Jesup.

	12°	36′		$\underline{\odot}$
		3		Index correction
	12	39		
	6°	19′	30″	apparent h of $\underline{\odot}$
—		9	11	Refraction
+			9	Parallax
+		16	00	Semi-diameter
	6	26	28	True h of sun's center

6	26	28	= h on April 6th
	22	28	= change in δ for $23^h\ 50^m$
6	48	56	= h on April 7 as computed from h of April 6.
6	47	23	= h from observations on April 7.

COMPUTATION OF REFRACTION CORRECTION

$T = -11°\,F.;\ \lambda = 1.0881$

$\log \gamma \ldots\ldots = 0.05403$

$\log (\gamma^{\lambda}) \ldots = 0.05879$

$\log \alpha \ldots\ldots = 1.72673$

$\log \tan z\ . = 0.95530$

$\log r \ldots\ldots = 2.74082$

$r = 551''\ . = 9'\ 11''$

δ' =		6°	18′	55″
Δ =	+		4	25
δ =		6	23	20

The above computation and comparison is made to show that the single observation of April 6th at Camp Jesup, while imperfect, consisting of a single observation on the lower limb of the sun seen through clouds, still affords a rough check on the complete observations obtained 24 hours later at the same place. The agreement within less than 2′ is certainly a satisfactory check.

**Peary's observations at midnight, April 6-7th, 1909.
Made at a point 10 miles from Camp Jesup
in a direction away from Cape Columbia.**

	13°	14′		
	14	18	20″	
	13	14	20	
	14	18		
	13	46	10	
	6	53	05	apparent h
—		8	54	Refraction
+			9	Parallax
	6	44	20	true h
	6	34	30	$= \delta$

BY DEAD RECKONING FROM CAMP JESUP.

longitude = 140° 20′ E.

Time: 12^h 40^m a. m. (60th meridian)

— 10 watch correction

\+ 4

16 30 G. M. T.

— 2 24

16 27 36 G. A. T.

24

7 32 24 = 113° 06′

$t = 140° 20' - 113° 06' = 27° 14'$

COMPUTATION
OF REFRACTION CORRECTION.

Temp. = — 30° F.

$\log (\gamma^\lambda) \ldots = 0.07836$

$\log \alpha \ldots\ldots = 1.73143$

$\log \tan z \ . = 0.91814$

$\log r \ldots\ldots = 2.72793$

$r = 534'' = 8'\ 54''$

$\log \tan \delta = 9.0616548$

$\log \sec t = 0.0510248$

$\log \tan D = 9.1127102$

$D \ldots\ldots = 7° 23' 10''$

$\log \sin h = 9.0694639$

$\log \sin D = 9.1090916$

$\log \csc \delta = 0.9411805$

$\log \cos \gamma = 9.1197360$

$\gamma \ldots\ldots = 82° 25' 46''$

$\Phi = D + \gamma = 89° 48' 56''$

as scaled off map $\Phi = 89° 50'.5$

Peary's observations of April 7th, 1909, 12h 40m p. m. (watch) at Camp Jesup.

	13°	18′	20″	
	14	21	30	
	13	18		
	14	21	50*	
	13	49	55	Mean
		2		Index corr'n
	13	51	55	
	6	55	58	Apparent h
—		8	44	Refraction
+			9	Parallax
	6	47	28	True h
	83	12	37	True z

COMPUTATION OF REFRACTION CORRECTION.

Temp. $= -25°$ F.; $\gamma = 1.16877$

$\log \gamma \ldots = 0.06772$

$\lambda \ldots\ldots = 1.0766$

$\log (\gamma^{\lambda}) \;. = 0.07291$

$\log \alpha \ldots = 1.73179$

$\log \tan z = 0.91505$

$\log r \ldots = 2.71975$

$r = 524'' = 8'\,44''$

TIME OF OBSERVATION.

12h 40m p m. watch time

10 watch fast on 60th meridian M. T.

12 30 p. m. 60th meridian M. T.

$\delta' = +6°\ 41'\ 34''$

$\Delta\ \ +\ \ \ 4\ \ 14$

$\delta = +6\ \ 45\ \ 48$

COMPUTATION OF PARALLAX.

$\pi = 8''.8$; $\log = 0.944$

$\log \sin z = 9.996$

$\log p \ldots = 0.940$

$p \ldots\ldots = 9''$

* This observation is on the upper limb, although it was recorded with the symbol for the lower limb.

Peary's observations of April 7th, 1909, 6h 40m a.m. (watch) at Camp Jesup.

	12°	55′	30″	
	13	59		
	12	56		
	13	59	20	
	13	27	27	Mean
		2		Index corr'n
	13	29	27	
	6	44	43	Apparent *h*
—		9	04	Refraction
+			9	Parallax
	6	35	48	True *h*
	83	24	12	True *z*

COMPUTATION OF REFRACTION CORRECTION

Temp. = — 30° *F.*; γ = 1.18229

$\log \gamma \ldots = 0.07272$

$\lambda \ldots\ldots = 1.0800$

$\log (\gamma^{\lambda}) \ . = 0.07854$

$\log \alpha \ldots = 1.73086$

$\log \tan z = 0.92709$

$\log r \ldots = 2.73599$

$r = 544'' = 9'\ 04''$

COMPUTATION OF PARALLAX.

$\pi = 8''.8$; $\log \pi \ldots = 0.944$

$\log \sin z = 9.997$

$\log p \ldots = 0.941$

$p \ldots\ldots = 9''$

TIME OF OBSERVATION.

6h 40m a.m. watch time

10 watch fast on 60th Meridian M. T.

6 30 a. m. 60th Meridian M. T.

$\delta' = 6°\ 41'\ 34''$

$\Delta = -\ 1\ 25$

$\delta = 6\ 40\ 09$

Computation of the geographic position of Camp Jesup

by Hugh C. Mitchell.

According to CHAUVENET, vol. 1, p. 260.

April 7, 1909.

$6^h\ 30^m$ a. m. ;	h =	$6°\ 35'\ 48''$	δ =	$6°\ 40'\ 09''$
12 30 p. m. :	h' =	6 47 23	δ' =	6 45 48

$\lambda/2 = 3^h = 45°$; $1/2\,(h + h') =$ 6 41 35.5 ; $1/2\,(\delta + \delta') =$ 6 42 58.5

$1/2\,(h - h') = -$ 0 05 47.5 ; $1/2\,(\delta - \delta') = -$ 0 02 49.5

$\log \sin 1/2\,(\delta - \delta') = 6.9147426^n$	$\log \cos 1/2\,(\delta + \delta') = 9.9970094$
$\log \cos \lambda/2$ . . . . $= 9.8494850$	$\log \sin \lambda/2$ . . . . . $= 9.8494850$
$\log \sin C.\ \sin E$. $= 6.7642276^n$	$\log \sin C.\ \cos E$. $= 9.8464944$
$\log \sin C.\ \cos E$. $= 9.8464944$	$\log \sin E$ . . . . . . $= 6.9177330^n$
	$\log \cos E$ . . . . . . $= 9.9999999$
$\log \tan E$ . . . . . $= 6.9177332^n$	$\log \sin C$ . . . . . . $= 9.8464945$
E . . . . $= -0°\ 02'\ 50''.67$	C . . . . $= 44°\ 36'\ 29''.4$

$\log \sin 1/2\,(\delta + \delta') = 9.0680091$	$\log \cos 1/2\,(\delta + \delta') = 9.9970094$
$\log \cos 1/2\,(\delta - \delta') = 9.9999999$	$\log \sin 1/2\,(\delta - \delta') = 6.9147426^n$
$\log \sec C$ . . . . . $= 0.1475651$	$\log \sec D$ . . . . . . $= 0.0059406$
	$\log \csc C$ . . . . . . $= 0.1585055$
$\log \sin D$ . . . . . $= 9.2155741$	$\log \cos P$ . . . . . . $= 7.0711981^n$
D . . . . $= 9°\ 27'\ 18''.65$	P . . . . $= 90°\ 04'\ 03''.01$

$\log \sin 1/2\,(h + h') = 9.0665226$	$\log \cos 1/2\,(h + h') = 9.9970300$
$\log \cos 1/2\,(h - h') = 9.9999994$	$\log \sin 1/2\,(h - h') = 7.2265290^n$
$\log \sec C$ . . . . . $= 0.1475651$	$\log \sec H$ . . . . . . $= 0.0058995$
	$\log \csc C$ . . . . . . $= 0.1535055$
$\log \sin H$ . . . . . $= 9.2140871$	$\log \cos Q$ . . . . . . $= 7.3829640$
H . . . . $= 9°\ 25'\ 21''.23$	Q . . . . $= 90°\ 08'\ 18''.18$

$q = -0°\ 04'\ 15.''17$

(Continued on next page)

log cos H . . . = 9.9941005
log cos q . . . = 9.9999997

---

log cos β sin γ = 9.9941002
log cos β cos γ = 9.2140871

---

log tan γ . . . = 0.7800131
γ . . . . = 80° 34′ 38″. 75
$D + \gamma$ . . . . . = 90° 01′ 57″. 4

log sin γ . . . = 9.9941005
log cos β. . . . = 9.9999997
log cos $(D + \gamma)$ = 6.7552392

---

log cos φ cos τ = 6.7552389
log cos φ sin τ = 7.0865044

---

log tan τ . . . = 0.3312655
τ . . . . = − 64° 59′ 48″. 73
or 115 00 11.27

log cos τ. . . . . = 9.6259991
log sin τ. . . . . = 9.9572646

---

log cos φ. . . . . = 7.1292398
φ. . . . . = 89° 55′ 22″. 24

φ is the latitude of Camp Jesup.

POSITION OF CAMP JESUP

LATITUDE = 89° 55′ 22″. 24 north.
LONGITUDE = 137° west of Greenwich.

log cos H . . . . . = 9.9941005
log sin q . . . . . = 7.0924039^{n}

---

log sin β. . . . . . = 7.0865044

log tan 1/2 $(\delta + \delta')$ = 9.0709998
log tan 1/2 $(\delta - \delta')$ = 6.9147428^{n}
log tan $\lambda/2$ . . . . . = 10.0000000

---

log tan x . . . . . . = 5.9857426^{n}
x . . . . = − 0° 00′ 20″

115° 00′ 11″	115° 00′ 11″
+ 20	+ 20
− 45	+ 45
70 00	160 00
+ 67 30	− 22 30
− 35	− 35

longitude = 137° west

equation of time = − 35′

6 : 30 a. m. (60 M) = 10 : 30 G.M.T.
= − 22° 30′

12 : 30 p. m. (60 M) = 4 : 30 G.M.T.
= + 67° 30′

Azimuth of sun at 6 : 30 a. m.
= 180° − 160° = 20° E. of N.

Computation of the geographic position of Camp Jesup

by C. R. Duvall.

April 7, 1909.

Watch time of observation	=	$6^h\,40^m$ a. m.
Watch fast on 60th M. M. T.	=	10
60th meridian M. T.	=	6 30 a. m.
Greenwich M. T.	=	10 30 a. m.
Astronomical date (G. M. T.)	=	22 30 April 6.

Zenith distance of sun's center $= a'$	=	83° 24′ 12″
Polar distance of sun's center . $= b'$	=	83 19 51
Assumed colatitude . . . . $= c'$	=	0 04 37. 7
$s' = 1/2\,(a' + b' + c')$	=	83 24 20. 35
$(s' - b')$	=	0 04 29. 35
$(s' - c')$	=	83 19 42 .65

log sin $(s' - b') = 7.1158910$

log sin $(s' - c') = 9.9970492$

log csc b' . . . . $= 0.0029487$

log csc c' . . . . $= 2.8708500$

9.9867389

log sin $A'/2$ . . $= 9.9933694$

$A'/2$ . . . . $= 80°\,00'\,48''$

A' . . . . $= 160\;01\;36$

(Continued on next page)

April 7, 1909.

Watch time of observation . . . . . . =	12^h	40^m	p. m.
Watch fast on 60th M. M. T. . . . . . . =		10	
60th meridian M. T. . . . . =	12	30	p. m.
Greenwich mean time . . . . =	4	30	p. m.
Astronomical date (G. M. T.). . . . . =	4	30	April 7.

Zenith distance of sun's center $= a =$	88°	12′	37″
Polar distance of sun's center . $= b =$	88	14	12
Assumed colatitude . . . . $= c =$	0	04	37.7
$s = 1/2\ (a + b + c)$ . . . . =	88	15	43.35
$(s - b)$ . . . . =	0	01	31.35
$(s - c)$ . . . . =	88	11	05.65

log sin $(s - b)$ =	6.6462775
log sin $(s - c)$ =	9.9969205
log csc b . . . =	0.0030328
log csc c . . . =	2.8708500
	9.5170808
log sin A/2 . . =	9.7585404
A/2 . . . . =	34° 59′ 43″
A . . . . =	69 59 26
A′ . . . . =	160 01 36
A′ − A . . . . . =	90 02 10

A previous computation based on an assumed colatitude of

0° 04 37″.5

gave

A′ =	160°	08′	28″
A =	69	58	34
A′ − A =	90	09	54

Hence it is easily deduced that a colatitude of

0° 04′ 37″.76

Will give A′ − A = 90° very nearly; therefore the

Latitude of Camp Jesup = 89° 55′ 22″.24

In the above A and A' are not azimuths, but hour angles.

Longitude computation — Camp Jesup — by C. R. D.

April 7, 6:30 a. m.

Hour angle of sun's center = local apparent time . . . . = — 160°	= —	10^h	40^m	00^s
Equation of time	= +		2	19. 87
Local mean time	= —	10	37	40. 63
Greenwich mean time	= —	1	30	00
Difference in time = difference longitude =		9	07	40. 63

= 137° west of Greenwich.

April 7, 12:30 p. m.

Hour angle of sun's center = local apparent time . . . . = — 70°	= —	4^h	40^m	00^s
Equation of time	= +		2	15. 41
Local mean time	= —	4	37	44. 59
Greenwich mean time	= +	4	30	00
Difference in time = difference longitude =		9°	07′	44″. 59

= 137° west of Greenwich.

Azimuth. — It has been found by trial, and it is also evident *a priori*, that the azimuth of the sun in this latitude differs very little from the supplement of the hour angle of the sun. Therefore the azimuth of the sun at the time of observation, April 7, 1909, 6:40 a. m. (watch time) was 20° East of North. Likewise, assuming a longitude of 137° West of Greenwich, and a watch 10 minutes fast for the observation at supposed noon, April 6, 1909, the forward course derived from the sun was 70° West of North.

DISCUSSION OF ERRORS.

The geographic position given for Camp Jesup, namely:

$$\begin{aligned} \text{Latitude} &= 89° 55'.4 \text{ N.} \\ \text{Longitude} &= 137° \text{ W.} \end{aligned}$$

is the best obtainable value for the position of that point. It was computed from the observations of April 7, 1909 (6:30 a. m. and 12:30 p. m.); the only other observation obtained at Camp Jesup, the one of April 6 (12:50 p. m.) is of such slight weight compared with those of the 7th that it cannot be combined with them in obtaining a position and is not therefore competent to be used in computing a probable error of the position obtained. It serves however to give us a fair idea of the extreme limits of error of the observations, as do also the observations taken at midnight of April 6th, at a point 10 miles from Camp Jesup, in a direction away from Cape Columbia. This latter observation serves further to inform us in some degree of the accuracy of the values deduced for the refraction correction. This information is obtained by comparing the position of the point of observation at the end of the 10-mile traverse as fixed by its distance and azimuth from Camp Jesup with the position based on the observations of April 6th (midnight).

The discrepancy thus developed contains the accidental errors of observation at Camp Jesup and at the other point of observation; it contains the error in the estimated length of the traverse; and it contains *double* the error in the corrections for refraction applied to the observations.

The total discrepancy amounts to about 3′ (or 3 geographic miles), and it is easy to see that the effect of any correction which may be applied to eliminate it will move Camp Jesup further away from Cape Columbia by an amount of between 1 and 2 miles. The effect of this on Peary's nearest approach to the pole, 1.6 miles, would be to lessen that distance. The distance of nearest approach to the pole, 1.6 miles, was obtained graphically by plotting the position of Camp Jesup on a properly constructed chart, and laying out the direction and distance of the traverse of April 7th, (between 6:30 a. m. and 12:30 p. m.) and then scaling the length of the perpendicular from the pole to the line of march.

It was also obtained by computation, of the equation:
Distance of nearest approach to pole = co-latitude $\times$ sin 20°

This traverse (8 miles in length) was made in the direction of the sun from Camp Jesup at 6:30 a. m. April 7th, the azimuth of the sun at that time being about 20° east of north.

It is reasonable to believe that at the pole in April, when the sun is rising slowly throughout the 24 hours, the refraction for any given angle of elevation is nearly constant, changing but slowly as the earth and air receive a slowly increasing amount of the sun's heat. For this reason, in the preceding paragraphs it is asserted that the discrepancy referred to contains double the error of the refraction correction, since that error must have the same sign at both places. Now, in the more southern latitudes, such as that of Washington, D. C., where the sun rises and sets every 24 hours and has a marked culmination, the value of refraction at and around sunset (and sunrise) is not only large, but is changing rapidly, due partly to the cooling (or heating) of the atmosphere at such times. Further on in this paper are shown observations on the sun made with a sextant and mercurial horizon at Washington at just before sunset, and in them it is shown that the combined errors of observation and of computed refraction were always less than 2′.

In view of the evidence furnished by the observations at midnight of April 6th, 1909, and that furnished by the observations at Washington relative to the errors of observations with sextant and mercurial horizon, it is surely safe to claim that the combined errors from all sources of the observations at Camp Jesup are less than 2′. In other words the corrected elevations of the sun which were used in computing the position of Camp Jesup are probably not in error by as much as 2′.

In the following tables are given corrections to the computed latitude of Camp Jesup produced by making changes of 1′ to 5′ in the elevations of the sun (h and h') used in the computations.

TABLES.

Changes in the latitude of Camp Jesup for various assumed changes in the sun's altitude

Computed according to Chauvenet, vol. 1, p. 272:

$$d\varphi = -\sin A'\,dh + \sin A\,dh'$$

From the computation of the position of Camp Jesup:

$$A = 200^\circ;\ A' = 290^\circ$$

There are two cases.

1. Where dh and dh' are of the same sign:

$dh' =$

	0′	1′	2′	3′	4′	5′	
$dh = 0'$	0	$\mp$ .3	$\mp$ .7	$\mp$ 1.0	$\mp$ 1.4	$\mp$ 1.7	
1	$\pm$ .9	$\pm$ .6	$\pm$ .3	$\mp$ 0.1	$\mp$ 0.4	$\mp$ 0.8	
2	$\pm$ 1.9	$\pm$ 1.5	$\pm$ 1.2	$\pm$ 0.8	$\pm$ 0.5	$\pm$ 0.2	Values of $d\varphi$
3	$\pm$ 2.8	$\pm$ 2.5	$\pm$ 2.2	$\pm$ 1.8	$\pm$ 1.4	$\pm$ 1.1	
4	$\pm$ 3.8	$\pm$ 3.4	$\pm$ 3.1	$\pm$ 2.7	$\pm$ 2.4	$\pm$ 2.0	
5	$\pm$ 4.7	$\pm$ 4.4	$\pm$ 4.0	$\pm$ 3.7	$\pm$ 3.4	$\pm$ 3.0	

2. Where dh and dh' are of different signs:

$dh' =$

	0′	1′	2′	3′	4′	5′	
$dh = 0'$	0	$\pm$ .3	$\pm$ .7	$\pm$ 1.0	$\pm$ 1.4	$\pm$ 1 7	
1	$\pm$ 9	$\pm$ 1.3	$\pm$ 1.6	$\pm$ 2.0	$\pm$ 2.3	$\pm$ 2.6	
2	$\pm$ 1.9	$\pm$ 2.2	$\pm$ 2.6	$\pm$ 2.9	$\pm$ 3.2	$\pm$ 3.6	Values of $d\varphi$
3	$\pm$ 2.8	$\pm$ 3.2	$\pm$ 3.5	$\pm$ 3.8	$\pm$ 4.2	$\pm$ 4.5	
4	$\pm$ 3.8	$\pm$ 4.1	$\pm$ 4.4	$\pm$ 4.8	$\pm$ 5.1	$\pm$ 5.5	
5	$\pm$ 4.7	$\pm$ 5.0	$\pm$ 5.4	$\pm$ 5.7	$\pm$ 6.1	$\pm$ 6.4	

From the preceding tables it is seen that the maximum error which could be produced in the latitude of Camp Jesup due to errors of 2′ in the observations is 2′.6, and that this would result only when all errors were pulling in the same direction, that is when *dh* and *dh′* have different signs; we know however that the portion of *dh* and *dh′* due to error in the refraction correction have the same sign, and furthermore that accidental errors tend to cancel. We may then regard the 2′.6 as too large, and safely assert that the total error in the position of Camp Jesup is less than 2′.

In making the above statement we have not overlooked the change which would be produced by an actual and unconsidered error in the correction to the watch time of the observations. The computed latitude is not sensitive to changes in the watch correction, and an actual computation showed that a change of 10 minutes in time affected the computed latitude by less than 6″. This has been referred to earlier in this paper, where it was shown that the watch correction was known to within less than 5 minutes.

It seems proper to insert in this paper the results of a test which was made of the sextant and the mercurial horizon, since the quality of observations possible with these instruments has direct bearing on the accuracy of the observations made by Peary at Camp Jesup.

A TEXT OF THE SEXTANT AND MERCURIAL HORIZON.

It is of keen interest in connection with Peary's observations at the North Pole to know just what observing can be done with a sextant and an artificial horizon.

Mercury freezes at a temperature of —40° F. (or C.) and though we have not observed mercury as it approaches the freezing point, it is reasonable to believe that at —30° F., 10° above the freezing point, it has not so changed its physical appearance as to be unsuited for use as an artificial horizon, and —30° is the lowest temperature at which observations were made on the sun by Peary at the North Pole.

As the sextant limb is graduated down to zero and beyond, this limb offers no obstacle to the reading of a very small angle — in fact, a negative angle can be read with it. It may be stated that in observing the altitude of a heavenly body when it is close to the horizon, two main difficulties are encountered. These dif-

ficulties, which increase as the body approaches the horizon, are the narrowing of the apparent length of the artificial horizon as the incident rays make a greater angle with the normal to the mercury, and the gradual loss of distinctness of the images due to the ever increasing amount of atmosphere through which the light from the heavenly body approaching the horizon has to pass to reach the observer.

Desirous of getting a practical test of the limits of such observations on the sun when near the horizon, on February 5, 1911, Mr. C. R. Duvall, one of the co-authors of this paper, commenced observing the sun's apparent double-altitude, using a sextant and a mercurial horizon, at 4 hours and 8 minutes p. m. (75th M. standard time). At that time the sun's apparent altitude above the horizon was about 14°. Mr. Duvall continued observations until 5 hours and 14 minutes p. m., when, at an apparent altitude of less than 3°, the sun was obscured by clouds and further observing prevented.

On the afternoon of February 7, 1911, further observations were undertaken with a view of determining how low the sun could be observed in mercury, and to obtain an idea of the accuracy of such observations.

It might be well at this point to state that the sextant was of the standard type used in the Coast and Geodetic Survey for purposes of navigation, having a vernier reading to 10″. The artificial horizon was a shallow metal pan which was filled to the brim with mercury, and over which was placed, to protect it from disturbing air currents, the usual type of wind shield consisting of two plates of glass set in a suitable frame. By placing a block of wood under the pan it was elevated to such a height that the sash of the cover offered no obstacle to observing.

On this afternoon (Febr. 7) Mr. Duvall observed two sets, a set consisting of four separate observations, and then gave way to Mr. J. C. Gauger, an officer of the Coast and Geodetic Survey who had previously had no experience in this particular class of observing, though well trained in the use of the sextant in measuring horizontal angles between terrestial objects. Others present were Mr. Hugh C. Mitchell, the other author of this paper, and Mr. Charles Mourhess, a computer in the office of the Coast and Geodetic Survey. Mr. Mitchell marked the time, and Mr. Mourhess reversed the wind shield of the mercurial horizon when required. Mr. Duvall did most of the recording.

The sextant was tested and found without error. The watch used was compared with a standard in the instrument division of the Coast and Geodetic Survey and found to be 50 seconds fast on 75th M. standard time.

The observations were made from a window in the office building of the Coast and Geodetic Survey on New Jersey Avenue, Washington, D. C. The mercurial horizon was placed on a window ledge about 3 stories above the ground.

Observing was begun at about 4h 46m p.m. and continued till 5h 25m p.m. watch time. The line of sight passed over the southwest portion of the city of Washington,—some smoke from railway trains was in the air, and when observing was finished the sun was already well below the tops of several church steeples a half-dozen blocks away, and so faint as to be observable only with the naked eye, the shade glasses having been thrown back. Its shape was decidedly flat, the apparent flattening of the lower limb being much greater than that of the upper limb. Finally, the last observation made was on the upper limb, at an apparent altitude of 1° 06′, which when corrected for refraction and semidiameter reduces to a true elevation for the sun's center of less than 25′.

It should have been mentioned also that the apparent length of the mercurial horizon had become so narrow that the entire image of the sun could not be seen in it at once, yet the observing was stopped because the sun's light became too faint to give a definite reflected image.

Before giving the observations made in this test it is well to state, and with emphasis, that similar observations can be obtained by most any fair observer with a sextant and artificial horizon on any clear evening or morning, and so these are not to be considered as something to be taken on faith.

Observations of the double altitude of the sun.
Coast and Geodetic Survey Office, Washington, D. C., Feb. 7, 1911.

Set No.	Sun's upper or lower limb	Watch time of observation	Sextant reading	Shield D or R	Remarks
1	U	4h 44m 41s	17° 27′ 20″	D	Watch 50s fast on 75th meridian M.T.; Duvall observing.
	L	45 30	16 08 10	D	
	L	47 05	15 37 20	R	
	U	47 59	16 23 20	R	
2	U	4 48 59	16 02 30	R	
	L	49 29	14 45 50	R	
	L	51 21	14 05 50	D	
	U	52 50	14 46 20	D	
3	U	4 56 55	13 20 20	D	Gauger observing.
	L	57 49	11 57 30	D	
	L	58 51	11 35 20	R	
	U	59 40	12 22 40	R	
4	U	5 00 54	11 58 30	R	
	L	01 51	10 34 20	R	
	L	03 39	9 55 40	D	
	U	04 28	10 44 20	D	
5	U	5 06 04	10 11 10	D	
	L	08 40	8 09 00	D	
	U	10 40	8 35 30	R	
	L	12 55	6 42 00	R	
6	L	5 16 08	5 38 50	R	
	U	17 39	6 10 20	R	
	U	18 26	5 50 10	D	
	L	19 01	4 37 00	D	
7	L	5 20 06	5 17 20	D	
	U	21 47	3 38 20	D	
	U	22 52	3 20 40	R	
	L	23 19	4 14 40	R	
8	U	5 23 56	4 01 20	R	At close of observations thermometer read 42° F.
	L	24 34	2 44 50	R	
	L	25 12	2 31 30	D	
	U	25 50	3 19 20	D	
	U	5 26 25	3 06 30	D	* Lower limb in a haze; continued observing on upper limb as long as possible.
	U*	5 28 08	2 32 50	D	
	U	5 29 35	2 11 20	D	

In reducing these observations the most desirable test to be applied seemed to be one which would give a check on the actual observation itself—that is, give an idea of the size of the uncertainty of the observed elevation. Into this text would enter the accidental errors of observation and the error of the computed refraction correction, which, for very small elevations, might prove to be considerable. Accordingly it was decided to compute values for the elevation of the sun at the various times of observation, and to compare these values with those obtained by observation, after these latter had been corrected for parallax and refraction.

The computation was simply made by spherical trigonometry. In each spherical triangle the quantities known were: The co-latitude, the co-declination, and the hour angle. The latitude and longitude of the point of observation were closely known, there being a well determined astronomic station about 50 meters distant. They were:

$$\text{Latitude} = 38^\circ\ 53'\ 08''$$
$$\text{Longitude} = 5^h\ 08^m\ 01^s.7.$$

The declination was obtained from the American Ephemeris and the hour angle from the longitude and the watch reading corrected to 75th M. standard time. The watch correction of —50 seconds obtained by comparison was tested by computing the correction from the observations, and found to be satisfactory.

In the following table are shown the results of the computation, the columns being headed in such a way as to be self-explanatory.

Result of sextant observations made at Washington. D. C. February 7, 1911.

Set. No.	Observed elevation	Correction for refraction and parallax	Corrected elevation	Computed elevation	Diff.
1	8° 12′ 01″	− 6′ 24″ + 9″	8° 05′ 46″	8° 05′ 00″	+ 46″
2	7 27 34	− 7 00 + 9	7 20 43	7 19 48	+ 55
3	6 09 29	− 8 18 + 9	6 01 20	5 59 35	+ 1′ 45
4	5 24 06	− 9 15 + 9	5 15 00	5 13 05	+ 1 55
5	4 12 12	− 11 20 + 9	4 01 01	3 59 56	+ 1 05
6	2 47 02	− 15 17 + 9	2 31 54	2 31 30	+ 24
7	2 03 52	− 18 11 + 9	1 45 50	1 45 56	− 6
8	1 34 38	− 21 10 + 9	1 13 37	1 14 46	− 1 09

The kernel of these observations and of their reduction may be briefly stated to be as follows: The upper limb of the sun was observed, using a sextant and a mercurial horizon, at an apparent elevation as low as 1° 06′, at which time the sun's center was actually only about 25′ above the horizon, the true elevation of the upper limb being about 41′. In none of the observations made at Washington were the combined errors of observation and refraction correction as great as 2′.

CONCLUSIONS.

From the foregoing we must concede the truth of the following conclusions:

1. That observations with a sextant and mercurial horizon on a celestial body are possible even when the body is very close to the horizon. In the face of observations of about 1° altitude, Peary's observations of over 6° altitude at the Pole do not look difficult.

2. That the error of the computed refraction combined with the error of observation probably amounts to less than 2′ even when the observed body is very close to the horizon.

Applying the above conclusions to the observations and result at Camp Jesup, we feel justified in repeating our belief that any reasonable assumption that we may make regarding the various errors of observation and computation at Camp Jesup will not produce an error as great as 2′ in the computed latitude of that point. Further, any assumption made in the regard to the errors affecting the 10-mile traverse of the night of April 6th, must tend to move Camp Jesup farther away from Cape Columbia, and at the same time slightly nearer to the Pole. This displacement would hardly be more than 1 mile, but its effect on the nearest approach to the Pole, made on the traverse of the morning of April 7th, (between 6:30 and 12:30) would be to materially lessen that distance (1.6 miles) and to strengthen the statement that on the morning of April 7th, 1909, Rear Admiral Robert E. Peary, U. S. N. was within 1.6 geographic miles of the North Pole.

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